Thermal Analysis of HISTORM-100 Dry Storage Cask With Oxidation Considered Heterogeneous WH14X14 Fuel Assembly Using COMSOL MULTIPHYSICS Program

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1. Introduction

The use of cask type dry storage systems is inevitable as the wet storage pool becomes saturated. In a typical dry storage cask thermal analysis, homogeneous fuel assembly condition is applied, and thermal properties of a fresh cladding are used. Homogeneous fuel assembly condition makes it difficult to apply detailed conditions to the fuel rods. Oxide film formed on the fuel rods has an effect of reducing thermal conductivity. Therefore, the use of thermal properties of fresh cladding is a non-conservative evaluation method. In this study, thermal analysis of dry storage cask with oxidation considered heterogeneous assembly condition was performed.

2. Procedure and Result

In this study, thermal analysis of the HISTORM-100 dry storage cask with oxidation-considered WH14X14 heterogeneous fuel assemblies was performed using COMSOL MULTIPHYSICS 5.4 program.

2.1 Geometry and Mesh Setting

The specifications of HISTORM-100 CASK, MPC-24, and WH14X14 refer to HOLTEC INTERNATIONAL's FSAR. Geometry is composed of 4,021,868 meshes in total. The average quality of the mesh is 0.3707. Geometry and mesh are shown in Fig.1 below.

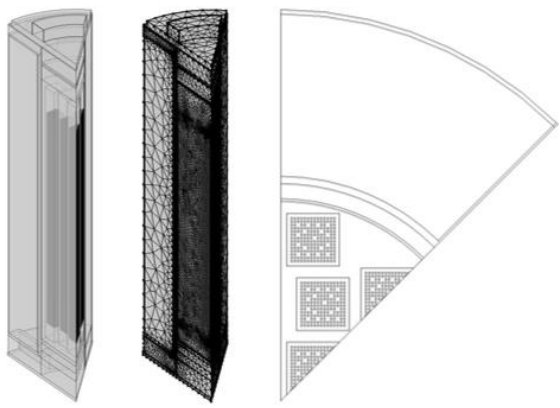

Fig. 1. Geometry and mesh of HISTORM-100 cask with WH14X14 heterogeneous fuel assembly.

2.2 Oxidation Considered Material Property

140um oxide thickness condition was used. Thermal conductivity and thermal transmittance were used to calculate oxidation considered conductivity. Specific heat and density were calculated to reflect the volume ratio. Oxidation-considered conductivity is shown in Fig. 2.

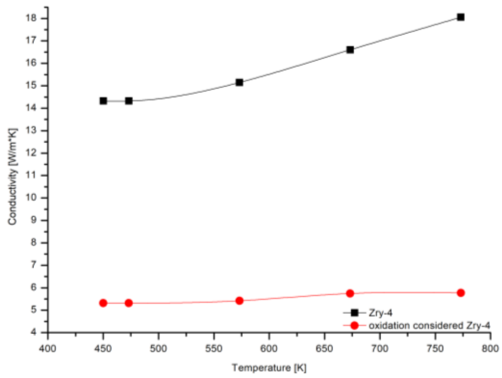

Fig. 2. Thermal conductivity of Zircaloy-4 and oxidation considered Zircaloy-4.

2.3 Computing Result

The difference between the FSAR result and the COMSOL MULTIPHYSICS program result is about 10℃. The difference in PCT (Peak Cladding Temperature) is about 3.1%. The results are shown in Fig. 3.

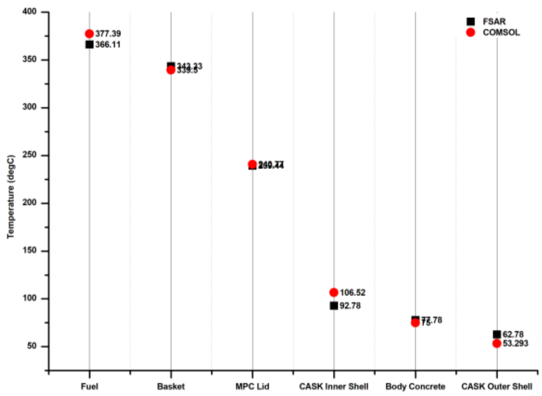

Fig. 3. Comparison of FSAR and COMSOL MULTIPHYSICS results.

Based on the above model, calculation using the oxidation considered thermal properties was performed. The PCT difference between oxidation considered model and oxidation not considered model is about 2℃. The calculation results are shown in Fig. 4.

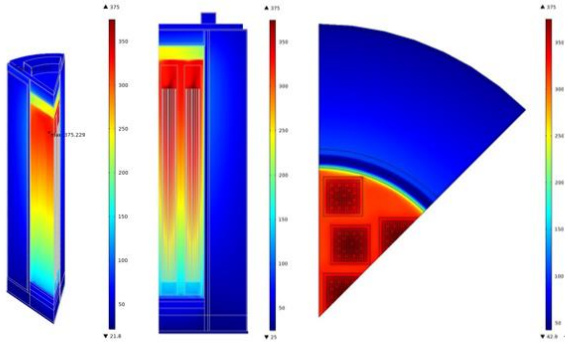

Fig. 4. 3D temperature profile, 2D temperature profile of 45° cutting plane, and 2D temperature profile of PCT height region.

3. Conclusion

According to the reference[2] data, up to 140um oxide can be formed under high burnup condition. PCT value of 140um oxide cladding was higher than the PCT value of fresh cladding by 2℃. In the case of spent fuel with high burnup condition, consideration of the changed thermal properties due to oxide will be more realistic and conservative evaluation.

REFERENCES

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[2] T. Motta, Adrien Couet, Robert J.Comstock, "Corrosion of Zirconium Alloys Used for Nuclear Fuel Cladding", Annual Review of Materials Research, Vol.45, 311-343 (2015).